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STUDIES OF GLACIAL HISTORY IN THE QUEEN ELIZABETH ISLANDS, CANADIAN ARCTIC ARCHIPELAGO

STOU-NG 21

STOCKHOLM 1975

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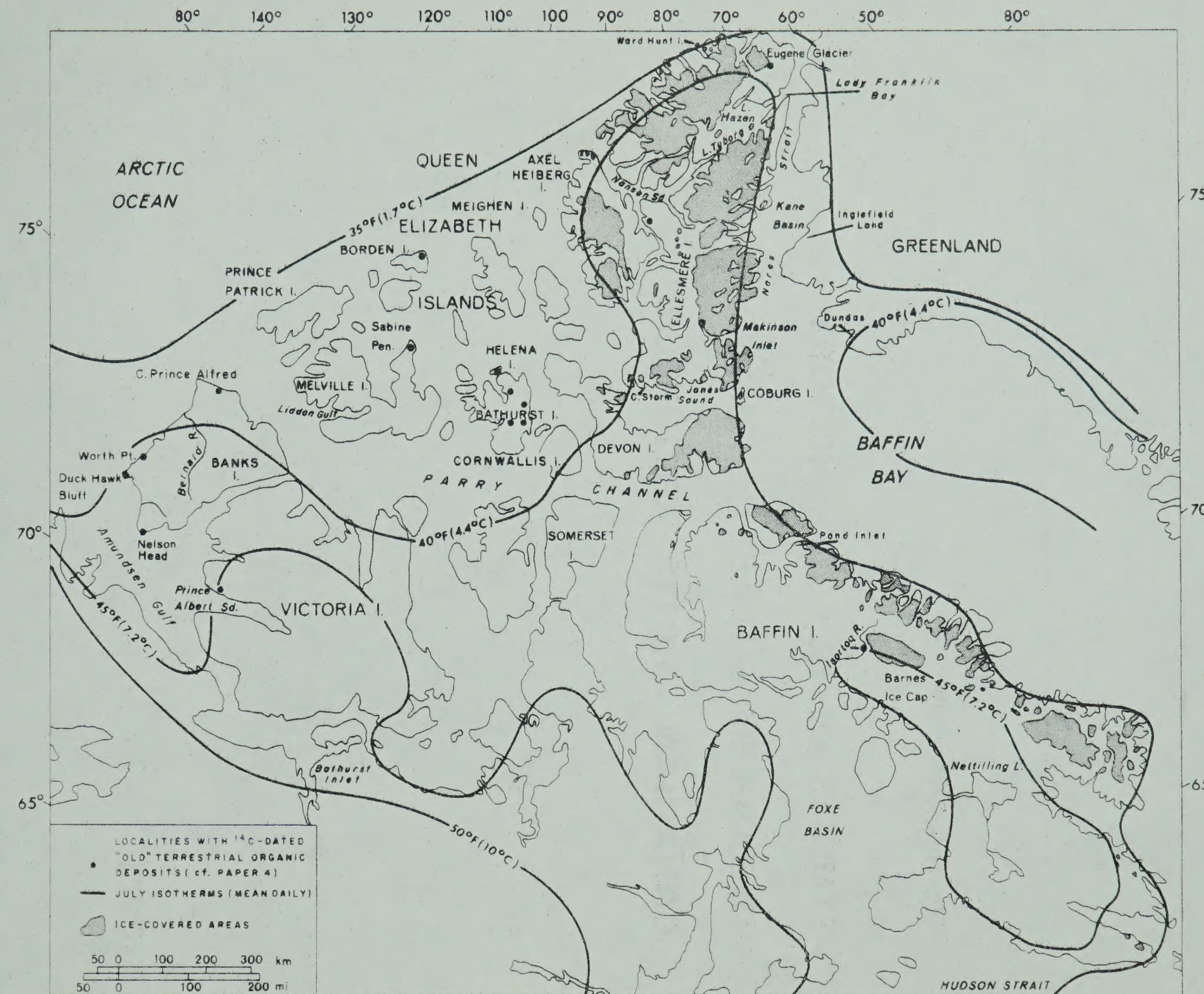

FIGURE I. LOCATION MAP, CANADIAN ARCTIC ARCHIPELAGO

INTRODUCTION

Since 1962 investigations aimed at elucidating the history of events during late Quaternary time have been pursued by the writer in various parts of northern Canada. In 1963, 1964, and in all field seasons excepting two since 1967 these studies have been concentrated in the Arctic Archipelago north of Latitude 74°. This part of the Archipelago, known as the Queen Elizabeth Islands, is separated from the southern islands by Parry Channel, the major east-west waterway (Fig. 1). Particular attention has been paid to southern Ellesmere Island and to Bathurst, Coburg, and Devon Islands during my own field work, but observations and collections made elsewhere in the Archipelago by other workers have been utilized also. The reconnaissance of this vast area, extending some 700 km westward from Baffin Bay and 300 km northward from Parry Channel, has been carried out with the support of light aircraft, usually a Piper Super-Cub equipped with oversize tires for landing on unprepared surfaces. Occasional use has been made of helicopters to visit localities inaccessible to fixed wing aircraft.

In the course of these studies particular emphasis has been placed on collecting samples for dating by the radiocarbon method, the aim being to establish a chronology for as much as possible of the last 50,000 years (conventional radiocarbon years)[1]. Detailed data concerning over 150 new radiocarbon age determinations — on driftwood, whale bones, ivory, marine mollusks, peat, marine algae, and terrestrial organic detritus — are presented. Also, the reliability of various materials and fractions for dating, based on comparative determinations, is treated at some length. The summary which follows, together with the five papers listed on the next page, constitute my doctoral dissertation, submitted to the Faculty of Science at the University of Stockholm.

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[1] Radiocarbon years based on the original or Libby half-life of 5568 ± 30 years as opposed to more accurate determinations made in Uppsala and elsewhere during the early 1960's.

LIST OF PUBLICATIONS

1. Studies of glacial history in Arctic Canada. I.
   Pumice, radiocarbon dates, and differential postglacial uplift in the eastern Queen Elizabeth Islands. Proceedings of the Symposium on Recent Crustal Movements held at Ottawa, Canada, March 1969.
   Canadian Journal of Earth Sciences 7, pp. 634-664.
   (Ottawa 1970).

2. Climatic implications of radiocarbon-dated driftwood in the Queen Elizabeth Islands, Arctic Canada. *In* Climatic changes in Arctic areas during the last ten-thousand years (Y. Vasari, H. Hyvärinen and S. Hicks, *Eds.*). Proceedings of a symposium held at Oulanka and Kevo, Finland, October 1971.
   Acta Universitatis Ouluensis, Ser. A, Scient. Rer. Nat. No. 3, Geol. No. 1, pp. 77-104.
   (Oulu 1972).

3. Former occurrence of *Mytilus edulis* L. on Coburg Island, Arctic Archipelago.
   Naturaliste canadien 100, pp. 51-58.
   (Québec 1973).

4. Studies of glacial history in Arctic Canada. II.
   Interglacial peat deposits on Bathurst Island.
   Canadian Journal of Earth Sciences 11, pp. 1025-1042.
   (Ottawa 1974).

5. Radiocarbon age determinations and postglacial emergence at Cape Storm, southern Ellesmere Island, Arctic Canada.
   Geografiska Annaler 57A, pp. 1-70
   (Stockholm 1975).

SUMMARIES OF PAPERS

Paper 1

This paper reports the discovery of dark brown pumice on raised beaches around Jones Sound, on both Ellesmere Island (four localities) and Devon Island (two localities). The pumice can be considered to have arrived simultaneously at all sites, and it thus provides an excellent time line for purposes of correlation. In this case radiocarbon age determinations on associated driftwood and whale bones at three of the six localities show that the pumice arrived approximately 5000 years ago. The origin of the pumice is unknown, although Iceland is a good possibility. In chemical composition and mode of occurrence on the beaches the andesitic pumice resembles similar material found on emerged strandlines in Nordaustlandet, Svalbard, as well as pumice reported from West Greenland, Denmark, Norway, and the northern part of European Russia.

The well-developed nature of the strandline with which the pumice is associated suggests that a stillstand of the shoreline, or a slower rate of emergence, was occurring close to 5000 years ago. In addition, there is evidence from a number of localities around the coasts of Svalbard and Scandinavia, where uplift was progressing less rapidly, that a transgression was underway at the same time.

Because the elevation of the pumice "horizon" rises toward the west along Jones Sound, the inference can be made that the former ice cover was thicker in the same direction. Analysis of radiocarbon age determinations on driftwood, marine mollusks, whale bones, marine algae and terrestrial organic detritus from elsewhere in the Queen Elizabeth Islands shows that there is a broad central zone, trending northeastward from Bathurst and Cornwallis Islands to north-central Ellesmere Island, where the shoreline formed 5000 years B.P. (= before present, where "present" is taken to be 1950) is now at an elevation of 25 m or more. From this pattern of regional shoreline deformation it is concluded that

during the maximum of the last glaciation an ice sheet, the Innuitian Ice Sheet, covered much of the Queen Elizabeth Islands, including all of the central inter-island area that is now sea. The Innuitian Ice Sheet is believed to have connected the Laurentide Ice Sheet to the south with the Greenland Ice Sheet to the east[2].

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[2]A different model has been proposed by J.H. England based on field work carried out in 1971 and 1972 in the Lady Franklin Bay area of northeasternmost Ellesmere Island (Fig. 1). In the published abstract of his Ph.D. dissertation, entitled "The glacial geology of the Archer Fiord/Lady Franklin Bay area, northeastern Ellesmere Island, N.W.T., Canada" (*Dissertation Abstracts International A - The Humanities and Social Sciences* 35, no. 4, p. 2149A, 1974) he states:

> "Local postglacial isobases over northeastern Ellesmere Island and Polaris Promontory, Greenland, show a strong upward tilt toward the margin of the Greenland Ice Sheet. This substantiates the conclusion of a restricted ice advance over northeastern Ellesmere Island during the last glaciation and consequently the resulting glacio-isostatic dominance of the Greenland ice load over the field area. Regional isobases constructed over northern Greenland and the Queen Elizabeth Islands, show a major ridge extending northeastward from the Eureka Sound area towards Greenland. The ice load from the last glaciation over the Queen Elizabeth Islands therefore appears to have produced a regional, westward extension of the north-western Greenland isobases."

The evidence presented in Paper 1, in which the shoreline delineated by the pumice horizon rises *westward* along Jones Sound, i.e., *away* from Greenland, cannot be accommodated in the isobase pattern proposed by England. The trend of the isobases around Jones Sound is discussed further in Paper 5 (note especially Figs. 5 and 6).

Paper 2

A brief résumé of the chronology of the Holocene marine incursion, and thus deglaciation, is presented in this paper. This introduction is followed by an analysis of the available radiocarbon age determinations on driftwood. Changes in the distribution of driftwood through time, especially with respect to the cover of sea ice and the development of ice shelves, are also discussed.

Numerous radiocarbon age determinations, mainly on marine mollusks, show that by 10,000 years ago the disintegration of the Innuítian Ice Sheet was well underway in the western part of the Queen Elizabeth Islands; the oldest age determination is one of 11,660 ± 370 years (GSC-354) from the south coast of Prince Patrick Island, the westernmost island in this part of the Archipelago. However, 10,000 years ago a lobe of the Laurentide Ice Sheet still impinged on the south coast of Melville Island. Between 9500 and 9000 years ago the whole of the Parry Channel opened up, and at the same time the sea started to penetrate northward into Nares Strait between Ellesmere Island and Greenland, as indicated by radiocarbon dates on both sides of the channel. Age determinations are now sufficiently abundant to indicate that by 9000 years ago most of the inter-island channels, and many tributary fiords leading into these channels, were free of glacier ice. By 8000 years ago all of the inter-island channels were open, with the possible exception of the northern part of Nares Strait, where Ellesmere Island and Greenland are closest together[3].

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[3]Since this paper was written the G.S.C. Radiocarbon Dating Laboratory has determined the age of a sample of *Portlandia arctica* shells collected by J.H. England from west of the innermost part of the Lady Franklin Bay system (toward Lake Hazen; cf. Fig. 1). The result, 8130 ± 200 years (GSC-1775), is reported by England in a paper entitled "Advance of the Greenland Ice Sheet on to northeastern Ellesmere Island" *Nature* 252, pp. 373-375, 1974). This date shows that the northernmost part of Nares Strait was open to the sea prior to 8000 years B.P., but as yet there are no age determinations exceeding 8000 years on Holocene marine shells or terrestrial organic detritus from the vicinity of Kane Basin itself.

The oldest driftwood logs, all either *Larix* sp. or *Picea* sp., found so far on emerged beaches in widely separated parts of the Archipelago are between 8500 and 8000 years old. Driftwood 6500 to 4500 years old is especially abundant in a number of localities — for instance northern Ellesmere Island, western Axel Heiberg Island, and the Jones Sound area between Ellesmere Island and Devon Island — indicating that at least as much open water as at present, and probably more, existed then[4]. It was during this interval, approximately 5000 years B.P., that the pumice reached the shores of Jones Sound. This period of more favourable sea ice conditions corresponds to the time when the Arctic tree-line was north of its present limit in both Eurasia and North America.

The marked decrease in the abundance of driftwood between approximately 4500 and 500 years B.P. is attributed to the onset of more severe sea ice conditions, which hindered the passage of wood through the various straits of the Archipelago. This interval coincides with the time during which ice shelves developed. These features are restricted today to the northern coast of Ellesmere Island, but they may have developed elsewhere between 4500 and 500 years ago, or at least multi-year sea ice may have blocked certain channels.

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[4]Several new determinations on driftwood collected in 1972 by G. Hattersley-Smith "inside" of the ice shelf south of Ward Hunt Island, northern Ellesmere Island, are all either "greater than" (3 pieces) or between 5000 and 6500 years old (4 pieces); cf. Table 3, p. 88, in Blake (1972); two of the pieces of post-glacial driftwood are within 1 m of present sea level; the other two are higher on the raised beaches. In addition to these samples, a piece of driftwood found imbedded in raised beaches near the northern tip of Axel Heiberg Island in 1973 by D.A. Hodgson is close to 4500 years old; other new wood samples from Somerset Island and Coburg Island reported in Paper 5 (Blake 1975) also fall within the 6500 to 4500 year-range.

Paper 3

This paper treats the present and past distribution of the blue mussel, *Mytilus edulis* Linné, in the Canadian Arctic. The distribution of marine animals, such as this mussel, bears on glacial history in that: 1) the area could not have been covered by glacier ice when the animals were living, and 2) the species or assemblage will often provide valuable information as to the past environment. In the case of *Mytilus edulis*, this shallow water pelecypod is not known to occur today north of Pond Inlet, northern Baffin Island; it is not found in the Queen Elizabeth Islands, although in 1940 it was discovered to be living in the vicinity of Thule (Dundas), Greenland in Latitude 76° 33' N. Likewise, although it occurs in postglacial deposits close to 8000 years old in eastern and northern Baffin Island, along the mainland coast around Bathurst Inlet, and in the Thule area of Greenland, it has not been found in marine deposits of post-glacial age in the Queen Elizabeth Islands. However, it formerly lived on Coburg Island (Latitude 75° 52.5' N) at the mouth of Jones Sound, some 350 km north of the localities in northern Baffin Island. The shells on Coburg Island, dated at >38,000 years (GSC-1425), are in a bed approximately 5.7 to 6.0 m above the normal position of high tide. The shell-bearing bed is underlain by a bed characterized by an abundance of calcareous algae and overlain by a non-fossiliferous sand, gravel, and cobble unit interpreted as representing a glacial episode. This unit is overlain, in turn, by a sequence of fossiliferous strata whose basal layers date from 9100 to 8800 years B.P.

The presence of *Mytilus edulis*, which is not a typical High Arctic pelecypod, suggests that the occurrence on Coburg Island is related to a time of more favourable environmental conditions, prior to the last glaciation, when sea level was higher than at present. Such conditions are most likely to have prevailed during the warm interval equivalent to the Sangamon Interglacial of continental North America.

Paper 4

Terrestrial organic deposits which pre-date the last glaciation in the Arctic Archipelago are the subject of this paper, special attention being paid to Bathurst Island. Seven radiocarbon age determinations from four sites on Bathurst Island are reported; they range in age from >30,000 years (GSC-1902) to >51,000 years (GSC-178-2). Nine determinations from six other localities in the Queen Elizabeth Islands (one each on Helena, Melville and Borden Islands, three on Ellesmere Island) range between >32,000 years (GSC-811) and >44,000 years (GSC-140-2) in age. In the southern part of the archipelago (south of Parry Channel), various finite radiocarbon dates in the 25,000 to 30,000 year-range have been obtained commercially. However, they have all produced "greater than" ages upon re-checking by the Radiocarbon Dating Laboratory at the Geological Survey of Canada. In only one locality, near the southern tip of Banks Island, has a reliable finite age been obtained; the value of 47,100 ± 1000 years (GSC-222-2) is the result of a 9-day count on *Salix* sp. wood from a sand-gravel-silt unit underlying till.

Dating of the peat deposits at two of the localities on Bathurst Island yielded ages of >50,000 years (GSC-165-2) and >51,000 years (GSC-178-2). At one of these sites, in the Stuart River valley, the peat (>1 m thick) contains the remains of aquatic plants, mosses and beetles which suggest that the deposit accumulated in a true interglacial interval, when conditions were somewhat more favourable than at present; i.e., Low Arctic versus High Arctic. These organic strata, which underlie silt containing marine pelecypods of postglacial age (8670 ± 100 years, GSC-1854), are assigned to the Stuart River Interglaciation.

As yet it is impossible to determine whether deposits at various sites relate to the same ice-free interval or not; nor have peat beds or other *in situ* organic remains been found which can be correlated with widespread deposits of mid-Wisconsin age in southern Canada. Some age determinations on terrestrial deposits (mostly lacustrine) in the 20,000 to 30,000 year-range have been

reported from sites in the northern part of the Arctic Archipelago and from adjacent Greenland, but because of the possible mixing of "old" carbon with fragments of postglacial tundra vegetation these dates are considered to be unreliable. Likewise the numerous finite age determinations on marine mollusks in the range of 25,000 to 40,000 years are suspect. Evidence is presented to show that it is safest to regard these dates as *minimum* age values; for example, shells dating in this range occur stratigraphically *below* a forest peat bed >50,000 years old in the Hudson Bay Lowland.

The absence of organic materials dating between 50,000 and 25,000 years B.P. in the Queen Elizabeth Islands may be because:

1) the area was ice-covered throughout Wisconsin time;
2) any mid-Wisconsin non-glacial interval was too short or had too severe a climate for deposits to accumulate;
3) organic deposits relating to this interval existed, but they have been eroded;
4) deposits of this age are present, but they have not been collected.

At present there is no concrete evidence against the hypothesis that the Queen Elizabeth Islands had a significant cover of ice throughout Wisconsin time. However, at only two of the 10 dated sites, both on Bathurst Island, do we have age determinations which eliminate the possibility of an ice-free interval during mid-Wisconsin time (i.e., 50,000 to 25,000 years B.P.)[5].

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[5]Since Paper 4 was published a new determination has been carried out on the peat representing moss bog tundra from near the Eugene Glacier, northern Ellesmere Island (Fig. 1); cf. GSC-1864, >43,000 years, Locality 9 in Table 3 in Blake (1974). The new result is >49,000 years (GSC-1864-2; three 1-day counts and one 3-day count in the 5-L counter at 4 atm).

Paper 5

This paper provides a detailed analysis of the pattern of postglacial emergence near Cape Storm, southern Ellesmere Island, based on more than 50 radiocarbon age determinations on a variety of materials, but mainly utilizing driftwood.

Evidence is presented, first, to show that this region was ice-covered during the last glacial maximum. Marginal drainage channels are abundant, striated and polished rock surfaces have been observed in a number of localities, and shell-bearing deposits of till, though thin, are widespread. Radiocarbon age determinations show that the sea entered the mouths of fiords earlier than it reached their heads. However, the best sort of indirect evidence is the ubiquitous presence of raised marine features of postglacial age, features which have formed as the land emerged from the sea following removal of the ice load. New age determinations on driftwood associated with the pumice (in addition to those reported and discussed in Papers 1 and 2), as well as dates on other finds of driftwood, have permitted isobases of equal emergence to be constructed. These isobases trend roughly northeast-southwest across southern Ellesmere Island and Devon Island to Somerset Island. They show that not only was the former ice cover thicker to the west, as indicated in Paper 1, but it was also thicker to the north. The tilt up toward the northwest is approximately 16 cm/km for the 6500 year-old strandline, 12 cm/km for the beach formed 5000 years B.P.

Dating of logs on the modern beach ridge near Cape Storm and on Melville and Axel Heiberg Islands, as well as wood on multi-year sea ice in Nansen Sound (between Axel Heiberg and Ellesmere Islands) shows that this wood is indeed "modern" (all <250 years old). Also, some of the driftwood (*Larix* sp. at the modern shore and on raised beaches) can be shown to derive from Eurasia on the basis of the resins it contains. At Cape Storm all the modern driftwood is within 2 m of the present shoreline, and no evidence was found that the imbedded wood on the raised beaches was thrown any greater distance over the contemporaneous sea

level. Thus the driftwood provides an excellent means of documenting the changing position of the shoreline through time, a period of more than 8000 years in the case of southern Ellesmere Island.

Numerous cross-check age determinations between driftwood and whale bones indicate that in this type of Arctic environment, utilizing the organic (collagen) fraction of whale bones for radiocarbon dating also gives reliable results, whereas in most cases determinations on the bone apatite fraction gives ages that are too young. In addition, Holocene marine mollusks yield reliable age values, and there is no evidence from areas of carbonate rocks, such as southern Ellesmere Island or Bathurst Island, that the radiocarbon ages of marine mollusks are more than 350 years older than the ages of contemporary terrestrial plants.

The highest beaches near Cape Storm are now close to 130 m above sea level, and age determinations on marine mollusks and whale bones near the limit of postglacial marine submergence show that the northwestern part of Jones Sound became open to the sea more than 9000 years ago. Between 9000 and 8000 years ago emergence proceeded at a rate of 7 m/century, and over one-half of the total emergence (70 m out of 130 m) since the initial incursion of the sea took place during this interval. By 6500 to 4500 years ago emergence had slowed to 0.8 m/century, and for the last 2400 years it has *averaged* <0.3 m/century. The age determinations are sufficiently numerous and closely spaced, especially between 6500 and 4400 years B.P., to confirm R.I. Walcott's earlier supposition that oscillations of sea level have not *exceeded* amplitudes of 2 m or periods >500 years during the interval between 8000 and 3500 years B.P.

The concentration of the pumice and the nature of the features associated with it suggest that its deposition may be related to:

1) a eustatic rise of sea level close to 5000 years ago;
2) a period of more open water, when wave action and storm surges would have been more effective;
3) a combination of these two factors.

The formation of the strandline where the pumice occurs is not believed to be related to a slowing-down or cessation of uplift due to a thickening of ice caps and glaciers. Many of the glaciers are presently impinging on undisturbed marine deposits; these glaciers are thus at, or are close to, the maximum extent attained since general deglaciation some 9000 years ago.

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